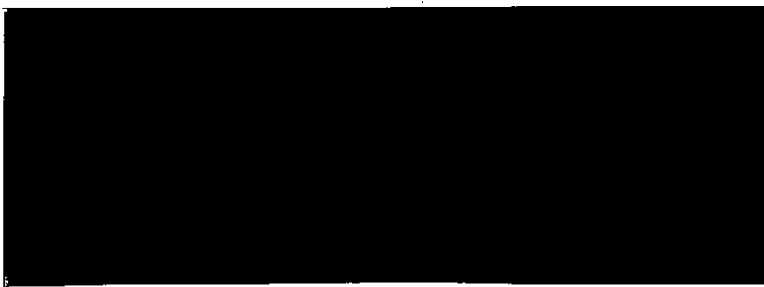


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FLAME-RESISTANT STRUCTURES FOR USE IN THE
APOLLO AND SKYLAB PROGRAMS Final Report
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DEVELOPMENT OF FLAME-RESISTANT
STRUCTURES FOR USE IN THE
APOLLO AND SKYLAB PROGRAMS

Contract No. NAS 9-12418
FINAL REPORT

September 1973

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DEVELOPMENT OF FLAME-RESISTANT STRUCTURES
FOR USE IN THE APOLLO AND SKYLAB PROGRAMS

Contract Number NAS 9-12418

Prepared by

Robert J. Coskren

for

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Structures and Mechanics Division
Houston, Texas

September 1973

FRL, An Albany International Company
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INTRODUCTION

The purpose of this program has been to develop candidate flame-resistant textile structures for use in the Apollo and Skylab programs. Materials have been designed and fabricated to meet certain end-use criteria established by NASA with emphasis on meeting established flammability standards. The program had three general phases:

1. Fabrication of candidate sample structures for evaluation by the Structures and Mechanics Division and/or NASA contractors.
2. Physical testing of the structures developed.
3. Supply of required quantities of specific items for fabrication into prototype and/or flight items for the Apollo and Skylab programs.

During the course of the work discrete tasks were delineated from time to time by NASA and acted upon by FRL. A listing of the disposition of the various tasks assigned during the course of the program is given below. Also shown is a list of the various certified items produced under Contract Numbers NAS 9-7397 and NAS 9-12418.

<u>Task No.</u>	<u>Description</u>	<u>Initiation Date</u>	<u>Completion Date</u>	<u>Monthly Report Reference</u>
201	Fabricate 50 yards of PBI Raschel Net (S-164)	1/14/72	1/26/72	March 72
202	Fabricate 400 yards of Nat. Nomex Raschel Net (S-173)	1/14/72	1/26/72	March 72
203	Fabricate the following: 1. 35 yds PBI Fabric (S-159) 2. 25 yds PBI Fabric (S-165)	1/14/72	2/29/72	March 72
204	Fabricate 50 yards of PBI Woven Fabric (S-151)	1/14/72	2/25/72	March 72
205	Fabricate 50 yards of Nat. Nomex Webbing (S-174)	1/26/72	1/31/72	March 72
206	Investigate T-treatment of Various PBI structures	2/15/72	4/30/72	Mar-Jun 72
207	T-treat 15 yards of PBI Raschel Net (S-164FX)	2/29/72	2/29/72	March 72
208	T-treat 30 yards of PBI rib knit fabric (S-161FX)	3/10/72	3/10/72	April 72

<u>Task No.</u>	<u>Description</u>	<u>Initiation Date</u>	<u>Completion Date</u>	<u>Monthly Report Reference</u>
209	T-treat the following: 1. 28 yds S-165 PBI fabric 2. 36 yds S-159 PBI fabric 3. 20 yds S-164 PBI raschel 4. 33 yds S-151 PBI fabric	3/15/72	3/17/72	April 72
210	T-treat the following: 1. 55 yds S-111 PBI webbing 2. 50 yds S-143 PBI webbing 3. 40 yds S-169 PBI webbing	3/29/72	4/10/72	April 72
211	Fabricate the following: 1. 50 yds S-143 PBI webbing 2. 20 yds S-170 PBI webbing	3/29/72	4/19/72	Apr-May 72
212	Fabricate 100 yards of S-169 PBI webbing	3/29/72	3/30/72	April 72
213	Fabricate and T-treat the following: 1. 390 yds PBI raschel (S-164FX) 2. 575 yds PBI rib knit (S-177FX) 3. 335 yds PBI fabric (S-165FX) 4. 200 yds PBI fabric (S-159FX) 5. 150 yds PBI webbing (S-169FX) 6. 200 yds PBI webbing (S-143FX)	4/13/72	8/29/72	May-Sept 72
214	Fabricate 48 PBI towels and washcloths	4/21/72	5/19/72	May 72
215	T-treat 44 yards of PBI webbing	4/24/72	4/21/72	May 72
216	Convert R.H. zippers to L.H. zippers	5/ 3/72	5/ 4/72	May 72
217	Fabricate stretch fabrics from T-treated PBI and Spandex yarn	5/18/72	5/22/72	June 72
218	T-treat PBI towels and washcloths made under Task 214	5/24/72	5/17/72	June 72
219	Fabricate stretch fabric from T-treated PBI and ADL elastomeric yarn	5/30/72	6/ 1/72	June 73
220	Fabricate and T-treat 50 yards of PBI webbing (S-141FX)	6/ 6/72	6/ 8/72	Jun-Jul 72
221	T-treat 25 yards of PBI Braided Cord (S-121FX)	6/ 6/72	6/ 2/72	July 72

<u>Task No.</u>	<u>Description</u>	<u>Initiation Date</u>	<u>Completion Date</u>	<u>Monthly Report Reference</u>
222	Fabricate and T-treat the following: 1. 50 yds PBI woven fabric (S-151FX) 2. 150 yds PBI webbing (S-141FX) 3. 150 yds PBI webbing (S-143FX)	6/ 8/72	8/31/72	Jul-Sept 72
223	Fabricate 7 yards of stretch fabric using T-treated PBI and ADL elastomeric fiber	8/11/72	7/11/72	Jul-Aug 72
224	T-treat 25 yards of PBI braided cord (S-121FX)	8/ 8/72	6/26/72	July 72
225	T-treat the following: 1. 155 ft PBI webbing (S-101FX) 2. 73 ft PBI webbing (S-169FX)	8/ 8/72	7/14/72	Aug 72
226	Fabricate PBI Wrapped ADL elastomeric yarns	8/ 9/72	7/31/72	Aug 72
227	Fabricate stretch knit fabrics from yarns made under Task 226	8/ 9/72	9/28/72	Aug-Oct 72
228	Fabricate 12 yards of flat jersey knit fabric (S-181)	8/ 9/72	9/ 8/72	Aug-Oct 72
229	Conduct PBI yarn processing trials at Southeastern Mass. University	8/14/72	9/12/72	Aug-Oct 72
230	Fabricate 100 yards of elastic tape from T-treated PBI yarn (transferred to Task 238)	8/25/72	1/12/73	Oct 72
231	T-treat 165 yards of PBI Braided Cord (S-121FX)	8/25/72	8/22/73	Oct 72
232	Microscopic analysis of fibrous components from SMEAT chamber	9/13/72	10/25/72	Oct 25, 72 special report
233	Fabricate and T-treat 800 yards of PBI rib knit fabric (S-177FX)	10/19/72	11/ 3/72	Oct-Nov 72
234	Fabricate 1000 yards of PBI braided cord (S-121)	11/ 3/72	11/20/72	Dec 72
235	Fabricate 25 yards of flat knit jersey fabric (S-181)	11/20/72	1/ 8/73	Dec 72 - Feb 73

<u>Task No.</u>	<u>Description</u>	<u>Initiation Date</u>	<u>Completion Date</u>	<u>Monthly Report Reference</u>
236	Fabricate 50 yards of 1-1/4" wide PBI webbing (S-168)	11/20/72	11/21/72	Dec 72
237	T-treat 75 yards of one inch wide PBI webbing (S-141FX)	11/30/72	11/28/72	Dec 72
238	Fabricate 107 yards of elastic tape from T-treated PBI yarn and ADL elastomeric fiber (S-185FX and S-186FX)	12/ 8/72	1/12/73	Jan-Feb 73
239	T-treat the following PBI webbings: 1. 14 yds FRL Style No. S-157 2. 25 yds FRL Style No. S-143	1/31/73	1/19/73	Feb 73
240	Fabricate and T-treat 100 yards of 2 inch wide PBI webbing (S-157FX)	1/31/73	1/25/73	Feb 73
241	T-treat 110 yards of PBI braided cord (S-136FX)	3/15/73	3/ 8/73	Apr 73
242	Fabricate and T-treat the following PBI webbings: 1. 100 yds FRL Style No. S-141FX 2. 100 yds FRL Style No. S-169FX	3/15/73	4/ 3/73	Apr 73
243	Fabricate and T-treat 100 yards of broad woven PBI Fabric (S-151FX)	5/ 9/73	6/15/73	Jun 73
244	Fabricate 4000 ft of 1/4" diameter PBI braided cord (S-136)	9/10/73	5/21/73	Jun 73
245	Fabricate the following: 1. 1000 ft T-treated PBI braid (S-136FX) 2. 700 ft 1" wide PBI webbing (S-188) 3. 5 lbs of PBI sewing thread (S-152) 4. 600 ft 3/32" diameter PBI braid (S-121)	9/10/73	6/25/73	Jul 73
246	Fabricate 900 feet of 1/4" diameter PBI braided cord (S-136)	9/10/73	6/12/73	Jun 73
247	Fabricate 25 yards of elastic braid from PBI yarn and ADL elastomeric fiber	9/10/73	7/ 3/73	Jul 73
248	T-treat 15 yards of 1/4" diameter PBI braided cord (S-136FX)	9/10/73	7/11/73	Aug 73

LIST OF CERTIFIED ITEMS PREPARED
UNDER CONTRACTS NAS9-7397 and NAS-9-12418

<u>FRL Style No.</u>	<u>FRL Lot No.</u>	<u>Description</u>
S-101	397-19,26,61, 63,182,190, 211,402,425	1" wide helmet tie down webbing
S-101FX	418-75	T-treated 1" wide PBI webbing
S-102	397-29,33	1/4" diameter PBI braided cord
S-103	397-34,98,369	1-3/4" wide PBI webbing
S-104	397-39	PBI raschel knit for debris net
S-105	397-46,89	1-3/4" PBI webbing
S-106	397-56	1/4" diameter PBI braided cord (CNR treated)
S-108	397-62	1/8" diameter PBI braided cord
S-109	397-38,191, 426,438	1/4" diameter PBI braided cord
S-110	397-58	Beta tricot liner fabric
S-111	397-81,193	1" wide PBI webbing
S-111FX	418-41	1" wide PBI webbing (T-treated)
S-112	397-86	3/8" wide Beta tape (Teflon coated)
S-113	397-87	1/8" Teflon coated Beta braided cord
S-114	397-90	Teflon coated Beta raschel knit
S-115	397-97,101, 101A,121	Teflon coated Beta broad fabric
S-116	397-103	Teflon coated Beta yarn raschel knit debris net
S-117	397-104,106	13/16" wide PBI webbing
S-118	397-105	1-3/4" wide PBI webbing

FRL Style No.	FRL Lot No.	Description
S-119	397-107	PBI sewing thread
S-120	397-128	1/16" diameter Teflon coated Beta yarn braid
S-121	397-137,149, 151,459, 418-132,170	3/32" diameter PBI braided cord
S-121FX	418-60,71,87	T-treated 3/32" diameter PBI braided cord
S-122	397-140A	1/16" diameter PBI braided cord
S-123	397-141	3/32" diameter PBI braided cord
S-124	397-150,184, 195,314,433	1-1/4" wide PBI webbing
S-125	397-152	Teflon coated Beta yarn tricot fabric
S-126	397-157	Teflon coated Beta yarn braid, 3/64" diameter
S-127	397-163,175	Teflon coated Beta yarn, 1/32" diameter braid
S-130	397-197	Natural Teflon yarn 3/200-300-20S/10Z
S-131	397-199	Natural Teflon yarn 5/400-60-0/3Z
S-132	397-200	Karma broad fabric
S-133	397-201	Karma broad fabric
S-134	397-208,301 463	Teflon tape, natural brass teeth, slide fasteners
S-135	397-209	Teflon coated Beta/Teflon ortho fabric
S-136	397-214 418-161,165	1/4" diameter PBI braided cord
S-136FX	418-155,164, 172	T-treated 1/4" diameter PBI braided cord
S-137	397-225	Filament PBI tricot fabric
S-138	397-229	Beta raschel tricot fabric for thermal blanket
S-139	397-231	Teflon coated 450 1/3 Beta yarn
S-140	397-232	Viton A unsupported gloves
S-141	397-224,250, 384,436,450, 418-65,156	1" wide PBI webbing

FRL Style No.	FRL Lot No.	Description
S-141FX	418-61,67, 137,157,160	1" wide PBI webbing (T-treated)
S-142	397-248	6 ounce spun PBI fabric (antistat finish)
S-143	397-249,287, 373,424,451 418-39,66	1-1/2" wide PBI tape
S-143FX	418-24,43,45, 62,68,147	1-1/2" wide PBI tape (T-treated)
S-144	397-251,321, 460	1/2" wide PBI tape
S-145	397-252	Teflon coated Beta yarn raschel fabric
S-146	397-253	Teflon coated Beta yarn raschel fabric
S-147	397-285	3/4" wide PBI tape
S-148	397-288,363, 371	1-1/2" wide Nomex tape
S-149	397-311	PBI double knit glove fabric
S-150	397-309	9/16" wide PBI tape
S-151	397-336, 418-9,21,92	6 ounce spun PBI 2/1 twill fabric (antistat finish)
S-151FX	418-28,97	6 ounce PBI 2/1 twill fabric (antistat finish, T-treated)
S-152	397-339,401 418-166	3 ply PBI sewing thread
S-153	397-356	Natural Nomex simplex knit
S-154	397-372,447 67877-114-3	1-1/4" wide PBI webbing
S-154FX	418-38	1-1/4" wide PBI webbing (T-treated)
S-157	397-455 67877-114-2 418-148	2" wide PBI webbing
S-157FX	418-146,150	2" wide PBI webbing (T-treated)
S-158	397-409	3 ounce spun PBI broad fabric
S-159	397-410,444 418-11,20,85	7 ounce fancy twill spun PBI fabric

FRL Style No.	FRL Lot No.	Description
S-159FX	418-29,91	7 ounce fancy twill spun PBI fabric (T-treated)
S-161	397-437	1 x 1 PBI rib knit
S-161FX	418-23	1 x 1 PBI rib (T-treated)
S-162	397-417	3/8" wide PBI tape
S-163	397-420,421	PBI covered spandex rib knit
S-164	397-423 418-3,50	Spun PBI raschel knit
S-164FX	418-12,13,27, 55,64	Spun PBI raschel knit (T-treated)
S-165	397-445 418-6,19	4 ounce plain weave PBI broad fabric
S-165FX	418-30,70	4 ounce plain weave PBI broad fabric (T-treated)
S-166	397-434,435, 454	3/4" wide PBI tape
S-168	397-449 418-136	1-1/4" wide PBI webbing
S-169	397-458 418-40,158	1-3/4" wide PBI webbing
S-169FX	418-42,63,74, 159	1-3/4" wide PBI webbing (T-treated)
S-170	397-457 418-44	1-3/4" wide PBI restraint harness webbing
S-171	397-462	Teflon tape, aluminum teeth, slide fastener
S-172	397-461	T-treated PBI broad fabric
S-173	418-4	Spun Nomex raschel net
S-174	418-5	1-3/4" wide Nomex restraint webbing
S-175	418-7	T-treated PBI spun fabric
S-176	418-22	PBI cord (8 ply, 3 cable)
S-177	418-49,90, 122	PBI rib knit
S-177FX	418-54,93, 126	PBI rib knit

FRL Style No.	FRL Lot No.	Description
S-178	418-51	PBI terry towelling
S-178FX	418-52	T-treated PBI terry towels
S-179FX	418-53	T-treated PBI terry washcloths
S-180	418-56	T-treated PBI yarn wrapped over spandex raschel fabric
S-181	418-69,72,73, 83-1,84,86,89, 98,100,142, 143,144	T-treated PBI yarn wrapped over ADL rubber flat knit fabric
S-182	418-81	Cabled PBI beading cord
S-183	418-82	16 carrier braid from 30/1 cc PBI yarn
S-184	418-83	12 carrier braid from 30/1 cc PBI yarn
S-185FX	418-140	3/4" wide elastic webbing (ADL rubber)
S-186FX	418-141,145	1-1/2" wide elastic webbing (ADL rubber)
S-187FX	418-168	Plain weave T-treated spun PBI fabric (7.6 ounce) ASTP suit
S-188	418-169	1" wide PBI webbing similar to MIL-W-4088, type II, Nomex
S-189	418-171	PBI/ADL elastomeric-fiber braided cord (16 ends of rubber)